IPSO Smart Objects
and related IoT Standards

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4. **IPSO:** Overview of the IPSO Objects, usage and registry.

Internet Engineering Task Force (IETF)
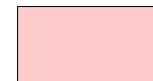
IETF: Circa 18 years of standards

|						
RFC 2689	RFC 3485	RFC 3544	RFC 3819	RFC 3940	RFC 3941	RFC 4629
RFC 4919	RFC 4944	RFC 5049	RFC 5401	RFC 5740	RFC 5856	RFC 5857
RFC 5858	RFC 6282	RFC 6469	RFC 6568	RFC 6606	RFC 6775	RFC 6690
RFC 7049	RFC 7228	RFC 7252	RFC 7388	RFC 7390	RFC 7400	RFC 7641
RFC 7668	RFC 7744	RFC 7925	RFC 7959	RFC 8075	RFC 8132	RFC 8152
RFC 8307	RFC 8323	RFC 8376	RFC 8392	RFC 8424	RFC 8516	...and more

Connectivity WGs   Application WGs   Security WGs

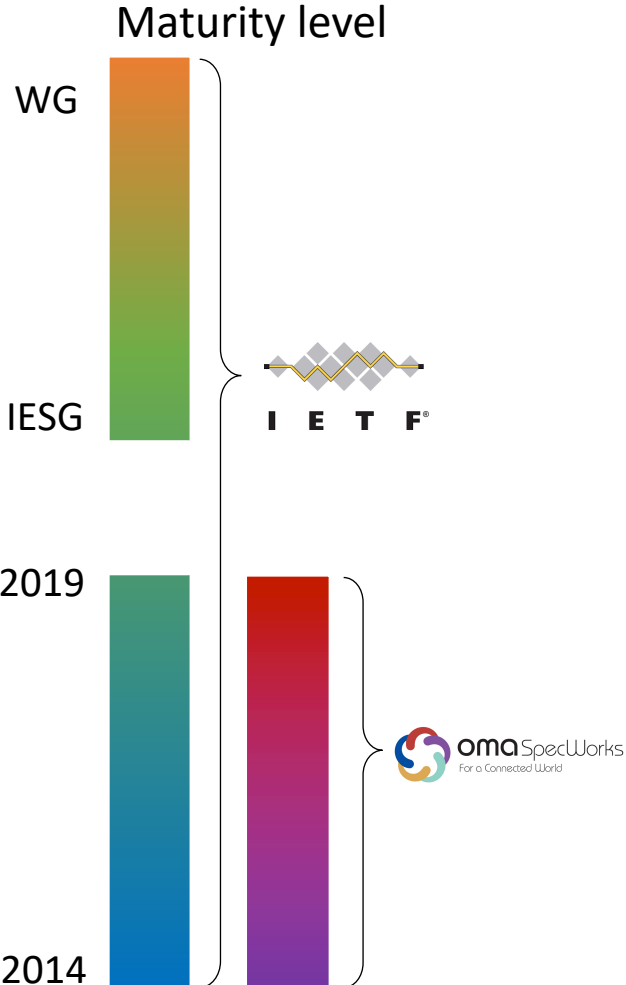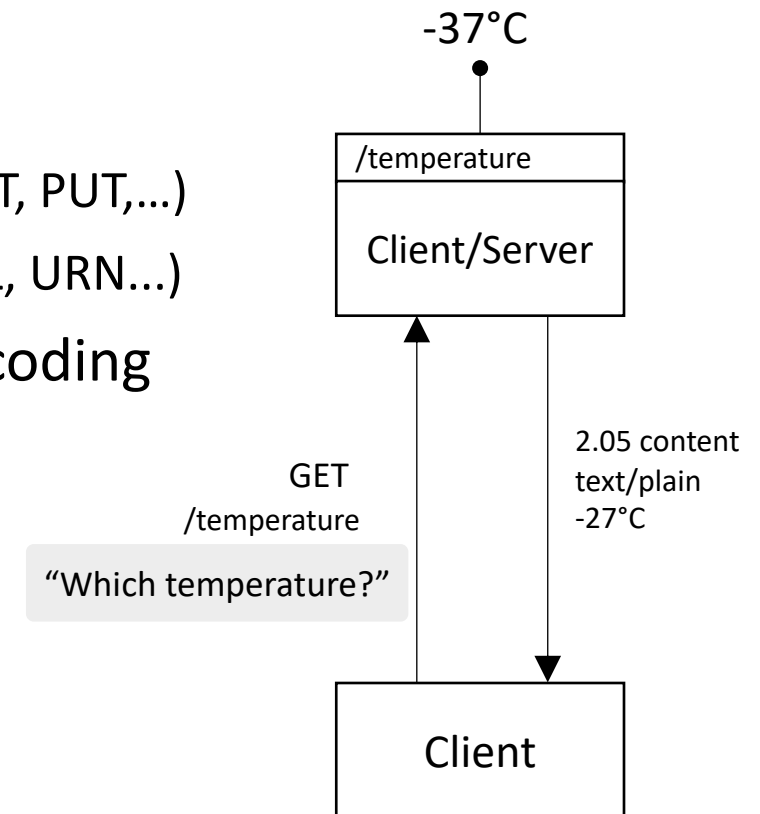# Standards Device Stack
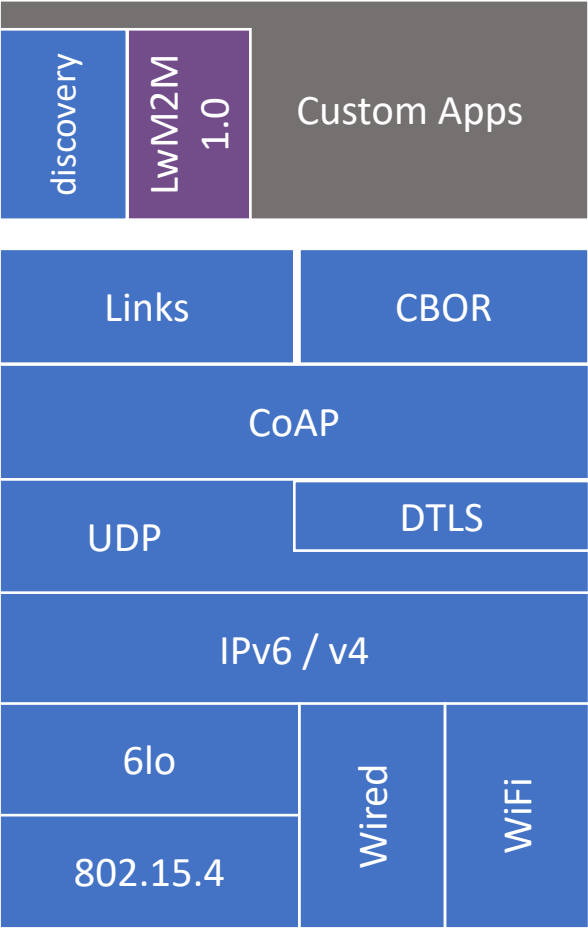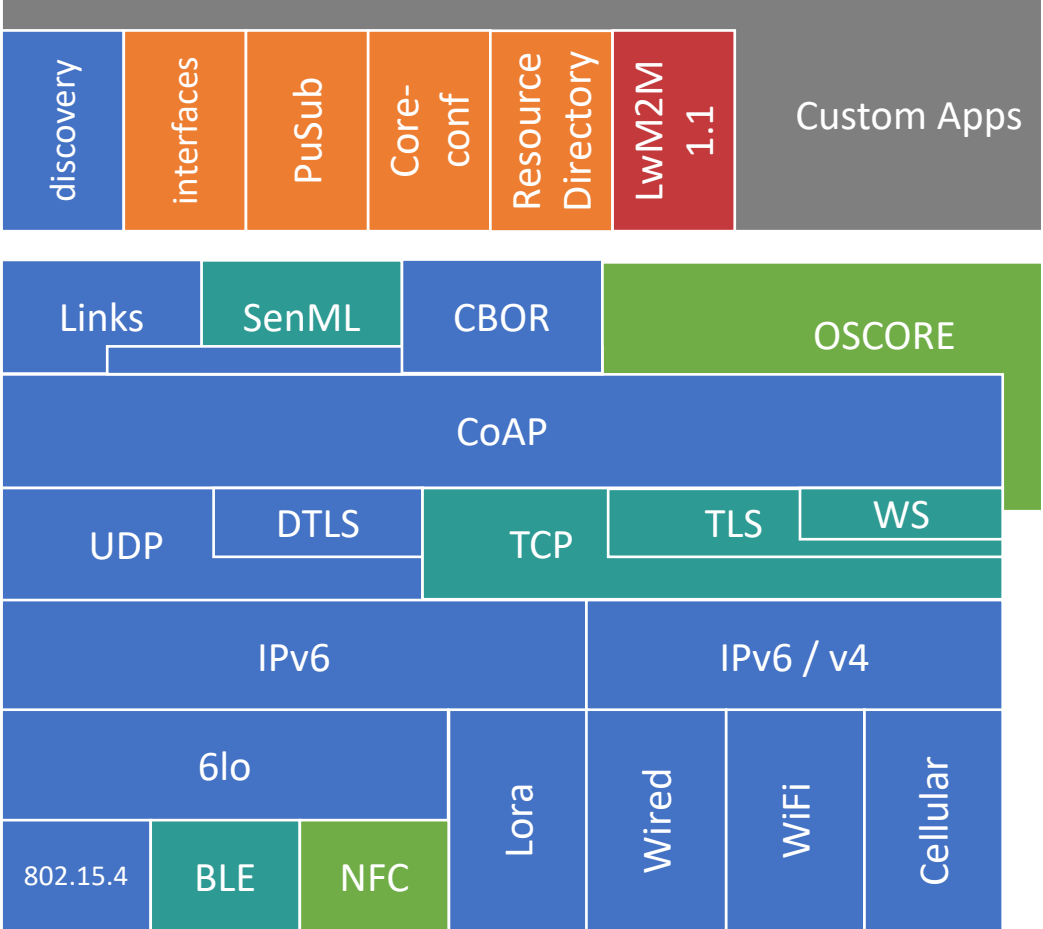
Constrained Application Protocol (CoAP)

The Constrained Application Protocol (CoAP)

- CoAP (RFC7252) implements HTTP's **REST** model
  - Simple devices: 100 to 250 KiB code and 10 to 50 KiB RAM
  - Each device can be client and server exposing resources
  - CoAP defines methods to access those resources (GET, POST, PUT,…)
  - Same key concepts borrowed from HTTP (Media types, URL, URN…)
- Has a compact 4-byte header, with simple options encoding
- Simple protocol, datagram (UDP, DTLS)
  - Reliability through header message type "*CON/NON*"
  - With TCP/TLS (RFC8323) support for NAT-ed environments
- The Resource Directory provides a directory service

-37°C

/temperature

Client/Server

GET
/temperature

"Which temperature?"

2.05 content
text/plain
-27°C

Client

The Constrained Application Protocol (CoAP)

- CoRELink (RFC6690) provides a link format
  - Reuses Web Linking RFC5988 for IoT.
  - Enables query string parameters for discovery
  - Enables attribute and relation types (rt, if, sz).
    <3303/0/5700>;rt="oma:lwm2m:temp";ct="0";obs=1
- Notifications available through *"observe"* header option
  - Can observe and add query parameters to the observation
    <3303/0/5700>?lt=0
- The *"/.well-known/core"* URI provides discovery
- Multiple serialization formats used with CoAP
  - SenML (RFC8428): Minimalistic JSON
  - CBOR (RFC7049): Binary serialization
- Multiple implementations available at coap.technology

-37°C

/ 3303/0/5700
/.well-known/core
Server

GET
/3303/0/5700;
rt="oma.lwm2m";
ct="0";obs=1

2.05 content
text/plain
-27°C
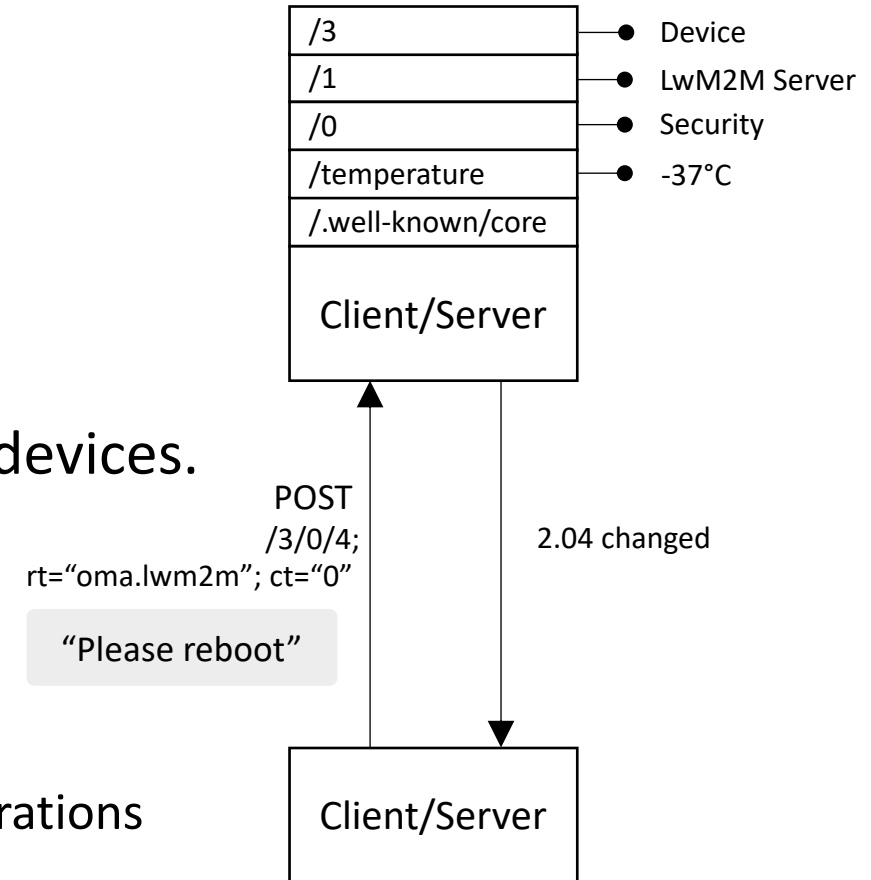
"Which temperature?"
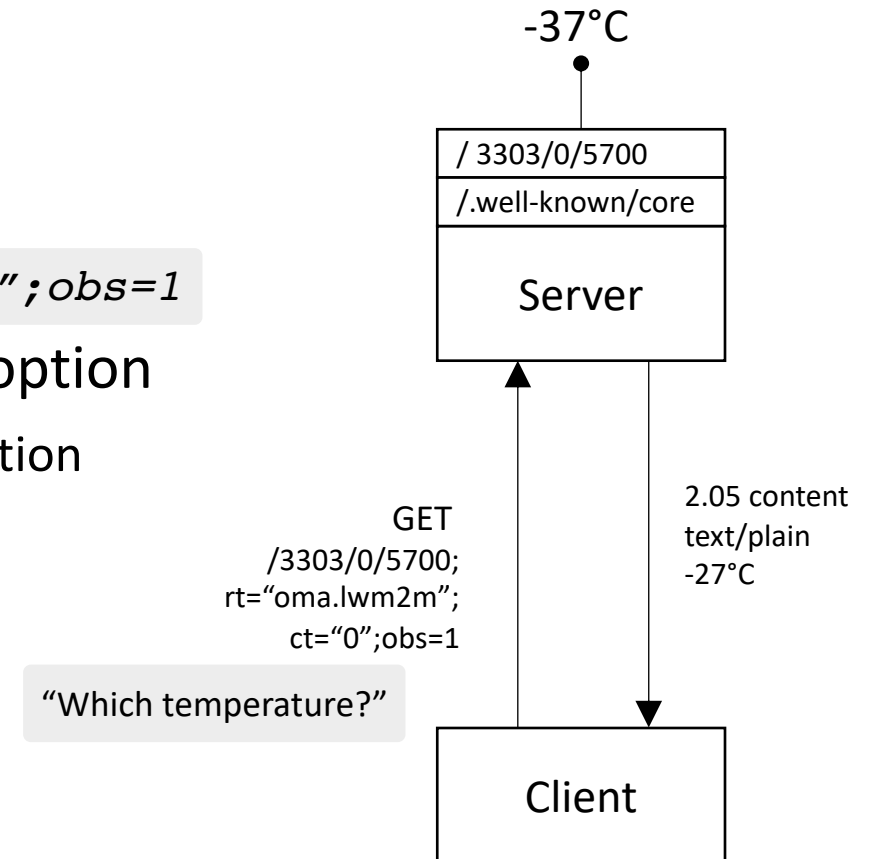
Client

Lightweight M2M Protocol (LwM2M)

The LightWeight M2M Protocol (LwM2M)

- Used for REST type of Device Management

  - Runs on top of **CoAP,** on top of **IP**

  - Device = LwM2M Client = at least CoAP Server

  - LwM2M Server is the Manager entity

- Supports Resource Registration on LwM2M Server

- Provides a set of interfaces for managing of constrained devices.

  - Bootstrap: provisions device, configures keying

  - Client Registration: RFC6690 and RD

  - Information Reporting: enables event subscription

  - Device Management & Service Enablement: management operations

/3	● Device
/1	● LwM2M Server
/0	● Security
/temperature	● -37°C
/.well-known/core	
Client/Server	

POST
/3/0/4;
rt="oma.lwm2m"; ct="0"

2.04 changed

"Please reboot"

Client/Server

The LightWeight M2M Protocol (LwM2M)

- Mapping of CoAP methods (GET,POST, PUT...) to **CRUD** operations

- Interaction with device through simple "Objects"

  o RWX, Access Control, Observation, Notification

  o Independent from underlying protocol stack (CoAP today)

  o Simple resource structure

  o Objects' resources are accessed with simple URIs:

    /{Object ID}/{Object Instance}/{Resource ID}

  o Multiple serializations:

    JSON, CBOR as well as other legacy.

- Common repository for all Objects (OMNA)

  - Enables interoperability and reusability

/3	● Device
/1	● LwM2M Server
/0	● Security
/ 3303/0/5700	● -37°C
/.well-known/core	
Client/Server	

POST
/3/0/4;
rt="oma.lwm2m"; ct="0"

"Please reboot"

2.04 changed
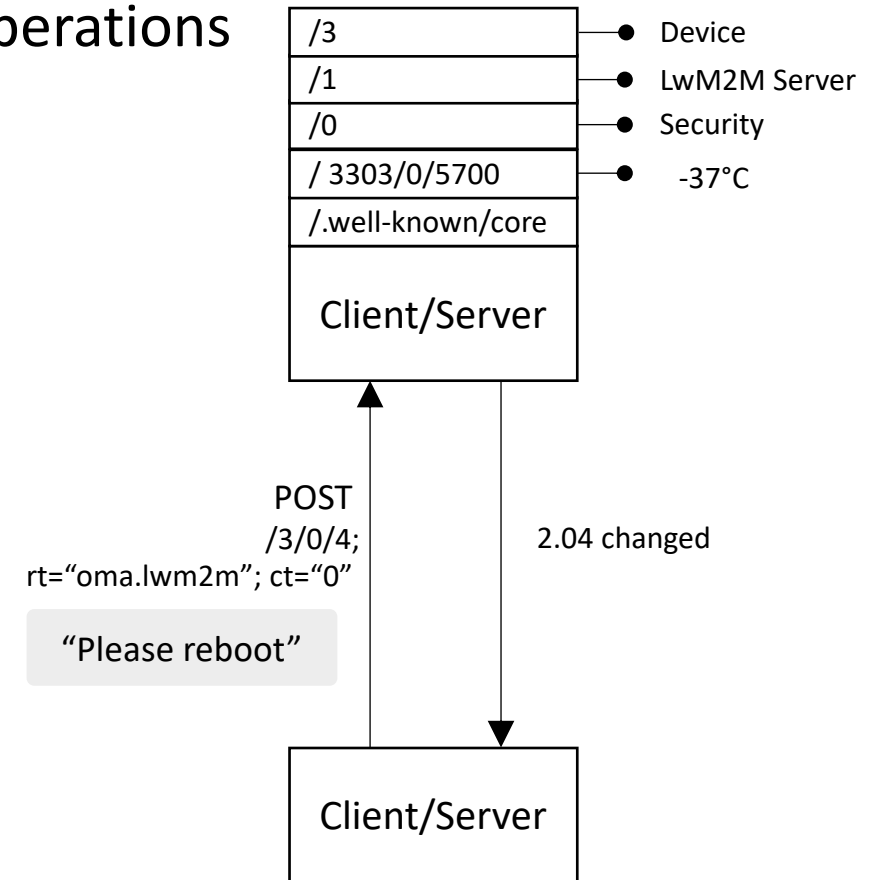
Client/Server

The LightWeight M2M Protocol (LwM2M)

Object Name	ID	Description
LwM2M Security	0	Keying material of a LwM2M Client to access a LwM2M server.
LwM2M Server	1	Data related to a LwM2M server.
Access Control	2	Information used to check whether a LwM2M Server has access to object.
Device	3	Device related information, including device reboot and factory reset function.
Connectivity Monitoring	4	Parameters related to network connectivity.
Firmware	5	Capability to update firmware
Location	6	Device location information
Connectivity Statistics	7	Information like transmit and receive counters
OSCORE	21	Provides security at the application layer

IPSO Smart Objects (IPSO)
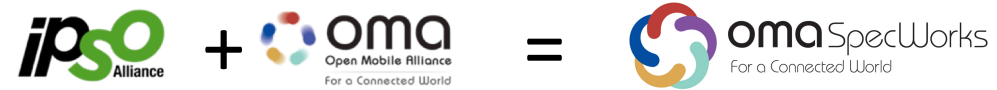
The **IP** for **S**mart **O**bjects **(IPSO)** device stack (recap)
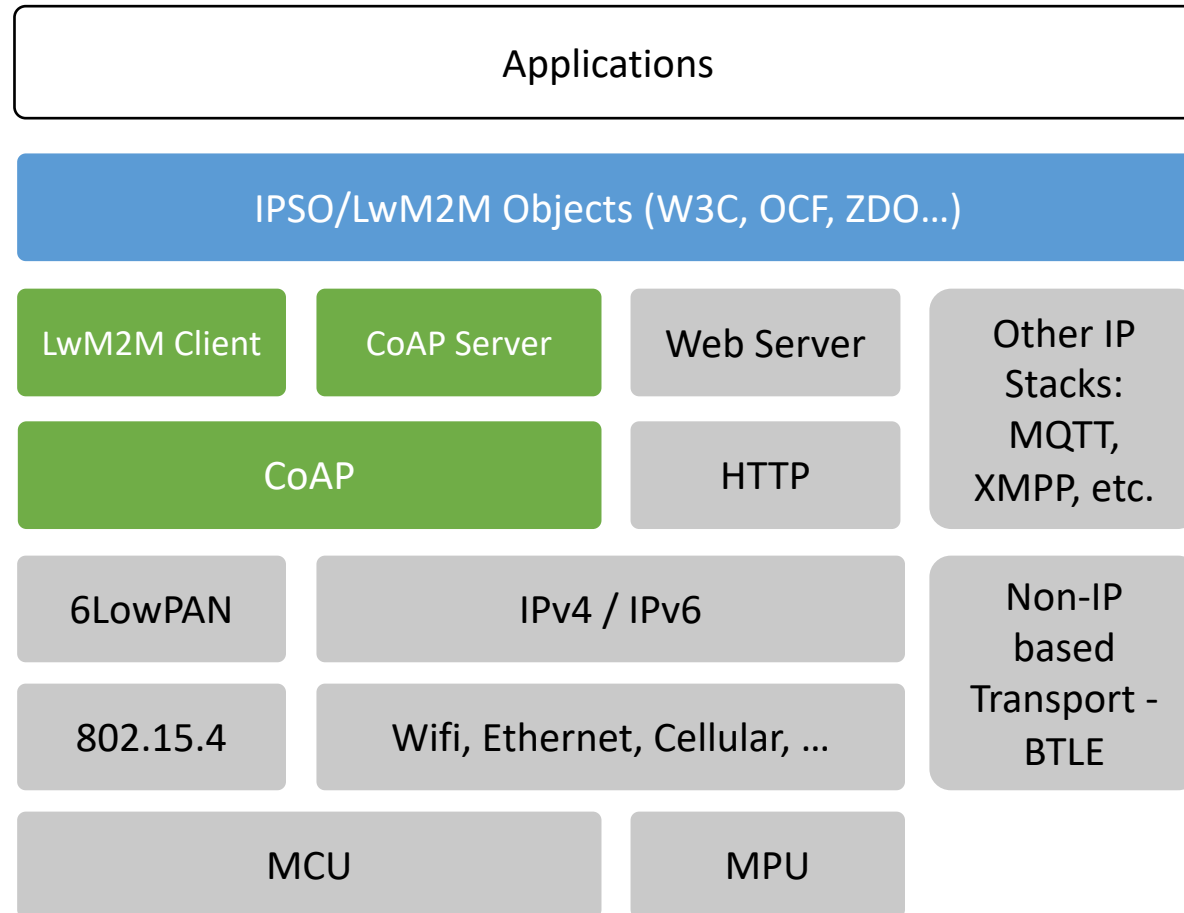
Applications	Application
IPSO/LwM2M Objects (W3C, OCF, ZDO...)	Data Models

| LwM2M Client | CoAP Server | Web Server | Other IP Stacks: MQTT, XMPP, etc. | API / Services |

| CoAP | | HTTP | | Application Protocol |

| 6LowPAN | IPv4 / IPv6 | Non-IP based Transport - BTLE | Routing |

| 802.15.4 | Wifi, Ethernet, Cellular, ... | | HW Network |

| MCU | MPU | Hardware |

**OMA** SpecWorks
For a Connected World

IETF

IPSO Object Structure

- Same URIs as LwM2M : `/{Object ID}/{Object Instance}/{Resource ID}`

  ```
  /3300/0/5700

  – 3300   Temperature Sensor

  – 0      Instance 0 of a Temperature Sensor

  – 5700   Resource having the current value
  ```

- Data Types (String, Integer, …) as LwM2M

- Operations (Read, Write, Create…) as LwM2M

- Object Linking and Core Link
  - Object Linking is used to refer to Objects within the device.
  - Allows composition without nasty large nested structures
  - Allows for complex objects (i.e. appliance made of several sensors)

- Web Linking to refer to external items (over CoAP).
  - Query parameters: `GET <URL>?rt="urn:oma:lwm2m:temp"`

- Extensible data model
  - Only few "Mandatory" Resources to enable interoperability
  - Use of versioning for model updates
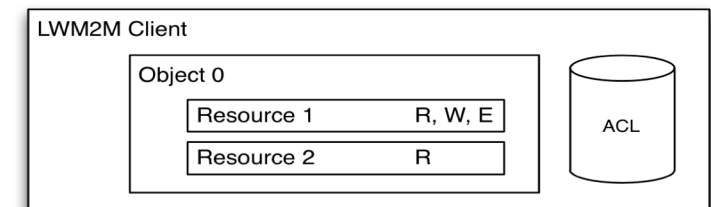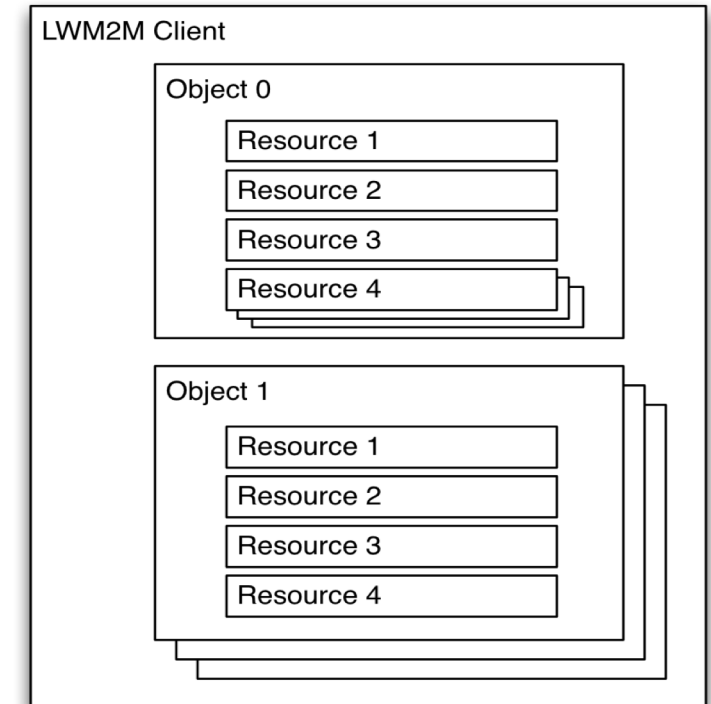
IPSO Example Temperature Object

Object definition

Name	Object ID	Instances	Mandatory	Object URN
Temperature	3303	Multiple	Mandatory	urn:oma:lwm2m:3303

Resource definitions

ID	Name	Operations	Instances	Mandatory	Type	Units	Description	
5700	Sensor Value	R	Single	Mandatory	Float	…	…	⎫
5601	Min Measured Value	R	Single	Optional	Float	…	…	⎬ Data
5602	Max Measured Value	R	Single	Optional	Float	…	…	⎭
5603	Min Range Value	R	Single	Optional	Float	…	…	⎫
5604	Max Range Value	R	Single	Optional	Float	…	…	⎬ Metadata
5701	Sensor Units	R	Single	Optional	String	…	…	⎭
5605	Reset Min and Max	E	Single	Optional	Opaque	…	…	} Actions

Ad-Hoc IPSO Object – Thermostat

Object info:

Object	Object ID	Object URN	Multiple Instances?	Description
Smart Thermostat	12300	urn:oma:lwm2m:x:12300	Yes	Smart Thermostat with multiple settings

Resource Info:

Resource Name	Resource ID	Access Type	Multiple Instances?	Mandatory	Type	Range or Enumeration	Units	Descriptions
Sensor Value	5700	R	No	Mandatory	Float		Per Units resource	Temperature measurement
Units	5500	R,W	No	Mandatory	String	ucum:degF, ucum:degC		Units for 5700
Application Type	5750	R,W	No	Optional	String			Name, e.g. "Hall Thermostat"
Cooling	5200	R	No	Optional	Boolean			1=cooling
Heating	5201	R	No	Optional	Boolean			1=heating
Heat Source	5203	R	No	Optional	String	"Emergency", "Normal"		Indicates heat source

Fan Timer Active	5204	R,W	No	Optional	Boolean				1=running
Fan Timeout	5205	R,W	No	Optional	String			UTS	Time for fan to stop
Energy Save Mode	5206	R,W	No	Optional	Boolean				1= Energy Save mode
Away Mode	5207	R,W	No	Optional	Boolean				0=Home, 1=Away
Setpoint	5208	R	No	Optional	Float				Desired Temperature
HVAC Mode	5209	R,W	No	Optional	String	"Heat", "Cool", "Heat-Cool"			System Mode
High Setpoint	5210	R,W	No	Optional	Float				Highest desired temperature
Low Setpoint	5211	R,W	No	Optional	Float				Lowest desired temperature
High Away Setpoint	5212	R,W	No	Optional	Float				Highest away mode temperature
Low Away Setpoint	5213	R,W	No	Optional	Float				Lowest away mode temperature

IPSO Smart Objects

Object	Object ID	Object	Object ID	Object	Object ID
Digital Input	3200	Current	3317	Gyrometer	3334
Digital Output	3201	Frequency	3318	Color	3335
Analogue Input	3202	Depth	3319	GPS Location	3336
Analogue Output	3203	Percentage	3320	Positioner	3337
Generic Sensor	3300	Altitude	3321	Buzzer	3338
Illuminance Sensor	3301	Load	3322	Audio Clip	3339
Presence sensor	3302	Pressure	3323	Timer	3340
Temperature Sensor	3303	Loudness	3324	Addressable Text Display	3341
Humidity Sensor	3304	Concentration	3325	On/Off Switch	3342
Power Measurement	3305	Acidity	3326	Dimmer	3343
Actuation	3306	Conductivity	3327	Up/Down Control	3344
Set Point	3308	Power	3328	Multiple Axis Joystick	3345
Load Control	3310	Power Factor	3329	Rate	3346
Light Control	3311	Distance	3330	Push Button	3347
Power Control	3312	Energy	3331	Multi-state Selector	3348
Accelerometer	3313	Direction	3332	Bitmap	3349
Magnetometer	3314	Time	3333	Stopwatch	3350
Barometer	3315				
Voltage	3316				

IPSO Reusable Resources

Resource	Resource ID	Resource	Resource ID	Resource	Resource ID	Resource	Resource ID
Digital Input State	5500	X Coordinate	5528	Reset Min and Max Measured Values	5605	Reactive Power Calibration	5816
Digital Input Counter	5501	Y Coordinate	5529	Analog Output Current Value	5650	Power Factor	5820
Digital Input Polarity	5502	Clear Display	5530	Sensor Value	5700	Current Calibration	5821
Digital Input Debounce	5503	Contrast	5531	Sensor Units	5701	Reset Cumulative energy	5822
Digital Input Edge Selection	5504	Increase Input State	5532	X Value	5702	Event Identifier	5823
Digital Input Counter Reset	5505	Decrease Input State	5533	Y Value	5703	Start Time	5824
Current Time	5506	Counter	5534	Z Value	5704	Duration In Min	5825
Fractional Time	5507	Current Position	5536	Compass Direction	5705	Criticality Level	5826
Min X Value	5508	Transition Time	5537	Colour	5706	Avg Load Adj Pct	5827
Max X Value	5509	Remaining Time	5538	Application Type	5750	Duty Cycle	5828
Min Y Value	5510	Up Counter	5541	Sensor Type	5751	On/Off	5850
Max Y Value	5511	Down Counter	5542	Instantaneous active power	5800	Dimmer	5851
Min Z Value	5512	Digital State	5543	Min Measured active power	5801	On Time	5852
Max Z Value	5513	Cumulative Time	5544	Max Measured active power	5802	Muti-state Output	5853
Latitude	5514	Max X Coordinate	5545	Cumulative active power	5805	Off Time	5854
Longitude	5515	Max Y Coordinate	5546	Active Power Calibration	5806	Set Point Value	5900
Uncertainty	5516	Multi-state Input	5547	Instantaneous reactive power	5810	Busy to Clear delay	5903
Velocity	5517	Level	5548	Min Measured reactive power	5811	Clear to Busy delay	5904
Timestamp	5518	Digital Output State	5550	Max Measured reactive power	5812	Bitmap Input	5910
Min Limit	5519	Digital Output Polarity	5551	Min Range reactive power	5813	Bitmap Input Reset	5911
Max Limit	5520	Analog Input State	5600			Element Description	5912
Delay Duration	5521	Min Measured Value	5601			UUID	5913

IPSO Object example

```xml
<?xml version="1.0" encoding="UTF-8"?>
<!-- MIT License
...
-->
<LWM2M  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="http://openmobilealliance.org/tech/profiles/LWM2M.xsd">
          <Object ObjectType="MODefinition">
                    <Name>Generic Sensor</Name>
                    <Description1>This IPSO object ...</Description1>
                    <ObjectID>3300</ObjectID>
                    <ObjectURN>urn:oma:lwm2m:ext:3300</ObjectURN>
                    <LWM2MVersion>1.0</LWM2MVersion>
                    <ObjectVersion>1.0</ObjectVersion>
                    <MultipleInstances>Multiple</MultipleInstances>
                    <Mandatory>Optional</Mandatory>
                    <Resources>
                              <Item ID="5700">
                                        <Name>Sensor Value</Name>
                                        <Operations>R</Operations>
                                        <MultipleInstances>Single</MultipleInstances>
                                        <Mandatory>Mandatory</Mandatory>
                                        <Type>Float</Type>
                                        <RangeEnumeration></RangeEnumeration>
                                        <Units></Units>
                                        <Description>Last or Current Measured Value from the Sensor</Description>
                              </Item>
                              . . . . Other Resources . . . .

                    </Resources>
                    <Description2></Description2>
          </Object>
</LWM2M>
```

XML Schema

Object Definition

Resource Definition

IPSO Serialization Formats

TLV (legacy)

```
C8 00 14 4F 70 65 6E 20 4D 6F 62 69 6C 65 20 41 6C
6C 69 61 6E 63 65
C8 01 16 4C 69 67 68 74 77 65 69 67 74 20 4D 32 4D
20 43 6C 69 65 6E 74
C8 02 09 33 34 35 30 30 30 31 32 33
C3 03 31 2E 30
86 06
   41 00 01
   41 01 05
88 07 08
   42 00 0E D8
   42 01 13 88
87 08
   41 00 7D
   42 01 03 84
C1 09 64
C1 0A 0F
83 0B
   41 00 00
C4 0D 51 82 42 8F
C6 0E 2B 30 32 3A 30 30
C1 10 55
```

SenML - JSON

```
[{"bn":"/3/0/","n":"0","vs":"Open Mobile Alliance"},
{"n":"1","vs":"Lightweight M2M Client"},
{"n":"2","vs":"345000123"},
{"n":"3","vs":"1.0"},
{"n":"6/0","v":1},
{"n":"6/1","v":5},
{"n":"7/0","v":3800},
{"n":"7/1","v":5000},
{"n":"8/0","v":125},
{"n":"8/1","v":900},
{"n":"9","v":100},
{"n":"10","v":15},
{"n":"11/0","v":0},
{"n":"13","v":1367491215},
{"n":"14","vs":"+02:00"},
{"n":"16","vs":"U"}]
```

IPSO Serialization Formats

SenML-CBOR

90 a3 21 65 2f 33 2f 30 2f 00 61 30 03 74 4f 70
65 6e 20 4d 6f 62 69 6c 65 20 41 6c 6c 69 61 6e
63 65 a2 00 61 31 03 76 4c 69 67 68 74 77 65 69
67 68 74 20 4d 32 4d 20 43 6c 69 65 6e 74 a2 00
61 32 03 69 33 34 35 30 30 30 31 32 33 a2 00 61
33 03 63 31 2e 30 a2 00 63 36 2f 30 02 01 a2 00
63 36 2f 31 02 05 a2 00 63 37 2f 30 02 19 0e d8
a2 00 63 37 2f 31 02 19 13 88 a2 00 63 38 2f 30
02 18 7d a2 00 63 38 2f 31 02 19 03 84 a2 00 61
39 02 18 64 a2 00 62 31 30 02 0f a2 00 64 31 31
2f 30 02 00 a2 00 62 31 33 02 1a 51 82 42 8f a2
00 62 31 34 03 66 2b 30 32 3a 30 30 a2 00 62 31
36 03 61 55

SenML-CBOR diagnostic

[{-2: "/3/0/", 0: "0", 3: "Open Mobile Alliance"},
{0: "1", 3: "Lightweight M2M Client"},
{0: "2", 3: "345000123"},
{0: "3", 3: "1.0"},
{0: "6/0", 2: 1},
{0: "6/1", 2: 5},
{0: "7/0", 2: 3800},
{0: "7/1", 2: 5000},
{0: "8/0", 2: 125},
{0: "8/1", 2: 900},
{0: "9", 2: 100},
{0: "10", 2: 15},
{0: "11/0", 2: 0},
{0: "13", 2: 1367491215},
{0: "14", 3: "+02:00"},
{0: "16", 3: "U"}]

Implementations and OMNA Registry

- Several Implementations support IPSO:
  - Example XML of the supported LwM2M and IPSO Objects in Leshan.
  - Sample C package for use of IPSO Objects in Contiki.
  - JS code templates of IPSO-defined devices code templates.
  - Sample Smart Objects Class can be used to create IPSO Smart Objects in your JavaScript applications.
  - BIPSO defines a set of BLE Characteristics that follows the IPSO Objects.
  - Contiki, Mbed and RIOT support IPSO Objects.

- Full object set available at the OMNA Registry:
  - http://www.openmobilealliance.org/wp/OMNA/LwM2M/LwM2MRegistry.html